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(54) SYSTEMS AND METHODS FOR IMPROVED SERVO DATA OPERATION

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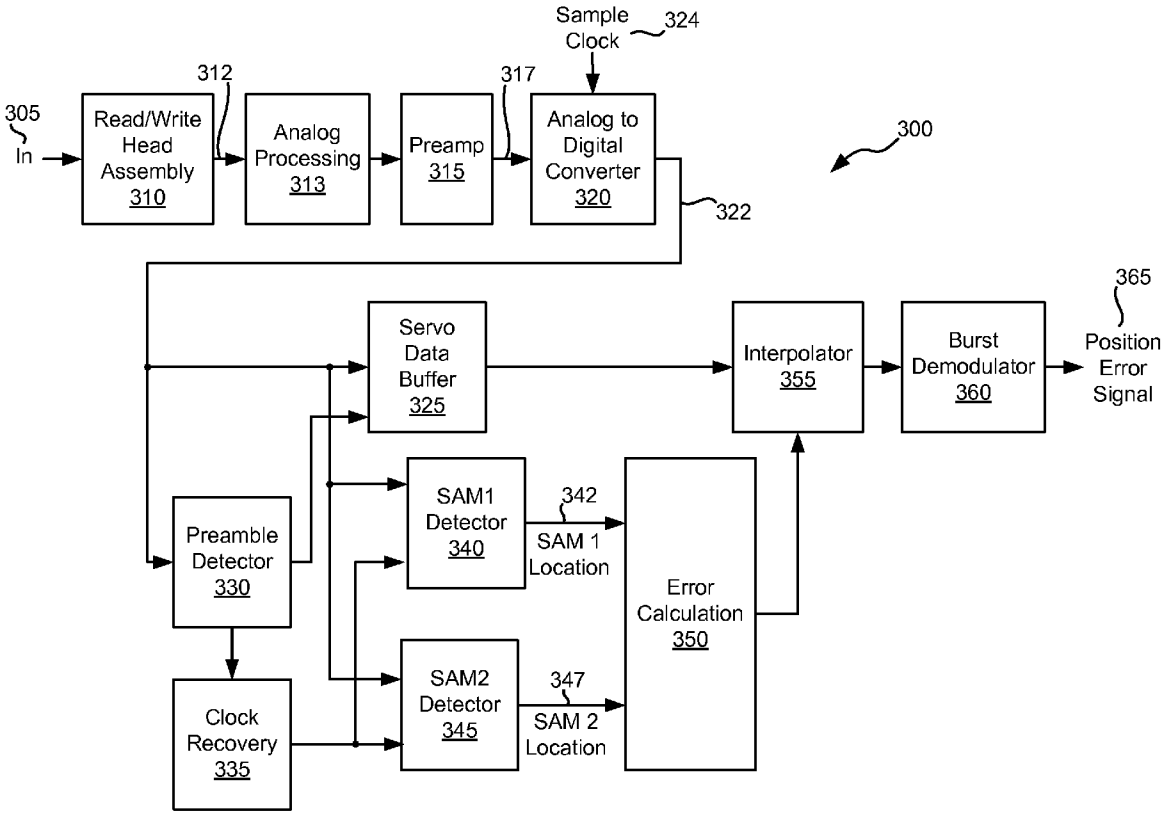
(57) **ABSTRACT**

Various embodiments of the present invention provide systems, methods and media formats for efficiently determining a position error of a head in relation to a storage medium. In one case, a system is disclosed that includes a storage medium with a series of data. The series of data includes a first defined marker and a second defined marker located a distance from the first defined marker, and position location data. The systems further include a first detector circuit that is operable to detect the first defined marker and to establish a location of the first defined marker, and a second detector circuit that is operable to detect the second defined marker and to establish a location of the second defined marker. The systems further include an error calculation circuit and an interpolation circuit. The error calculation circuit is operable to calculate an interpolation offset based at least in part on the location of the first defined marker and the location of the second defined marker. The interpolation circuit is operable to interpolate the position location data and to provide an interpolated position location data.



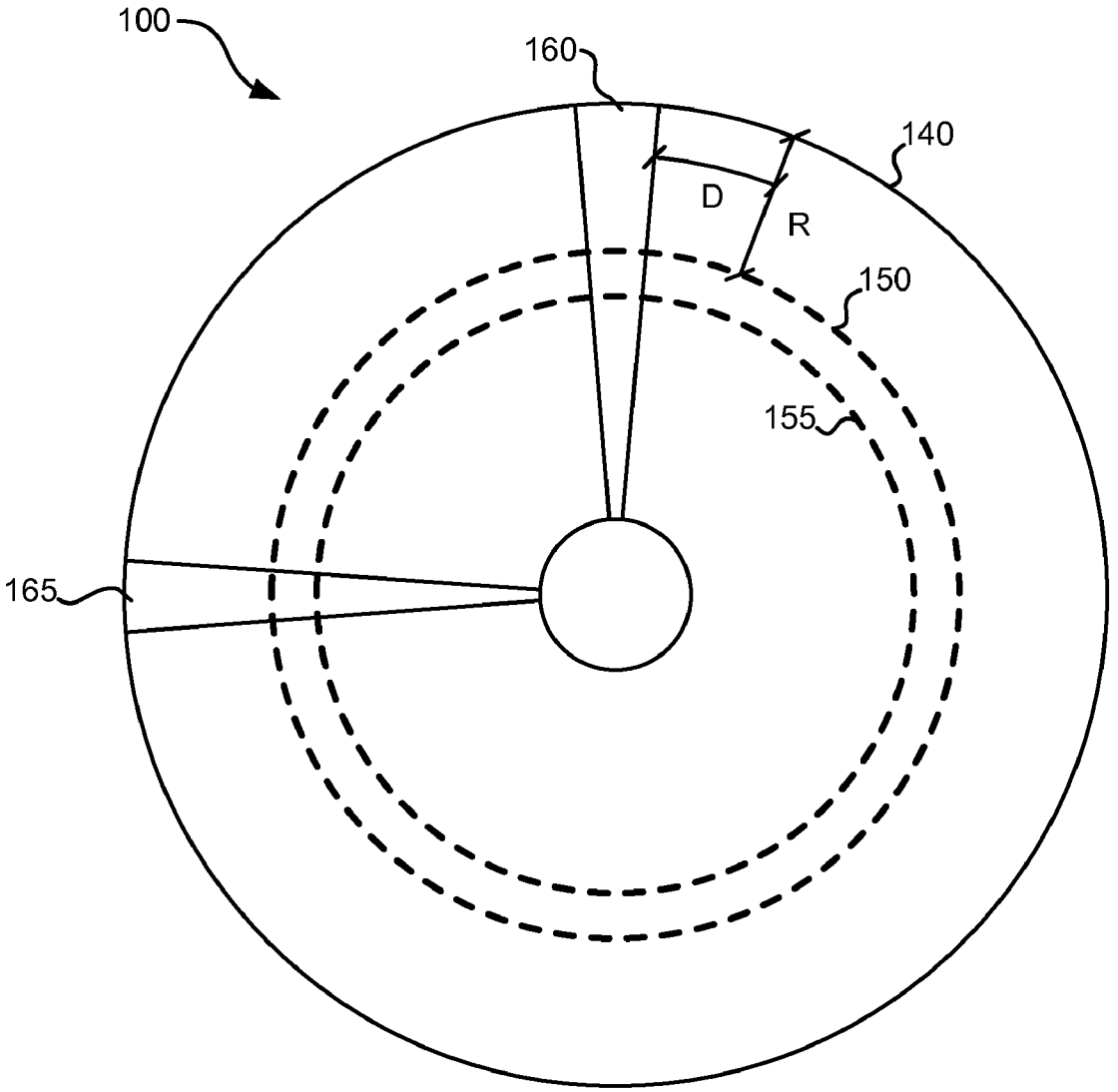


Fig. 1 (Prior Art)

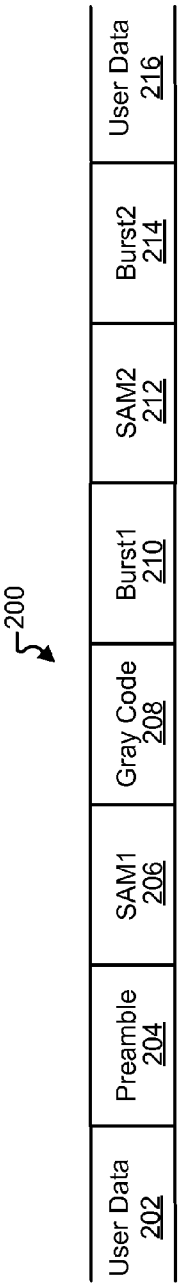

200
User Data 202
Preamble 204
SAM1 206
Gray Code 208
Burst1 210
SAM2 212
Burst2 214
User Data 216

Fig. 2

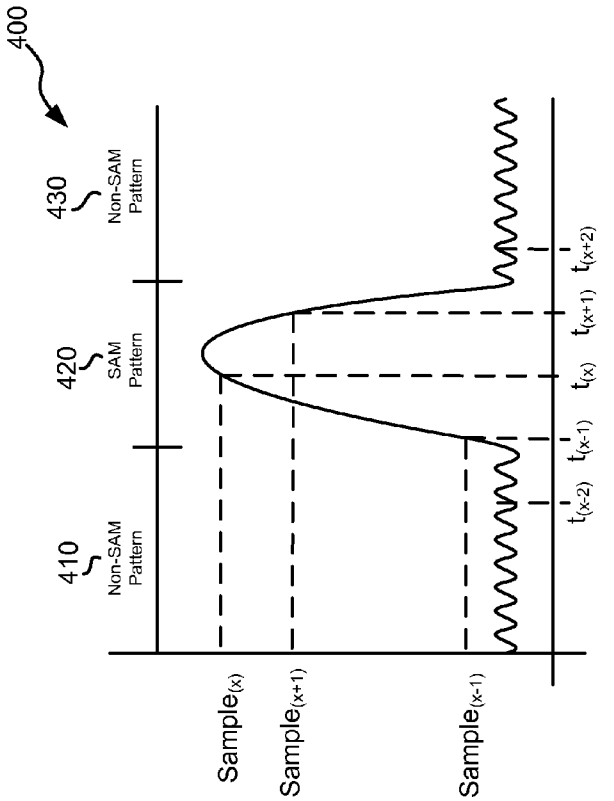

400
410
Non-SAM Pattern
420
SAM Pattern
430
Non-SAM Pattern
Sample(x)
Sample(x+1)
Sample(x-1)
t(x-2)
t(x-1)
t(x)
t(x+1)
t(x+2)

Fig. 4

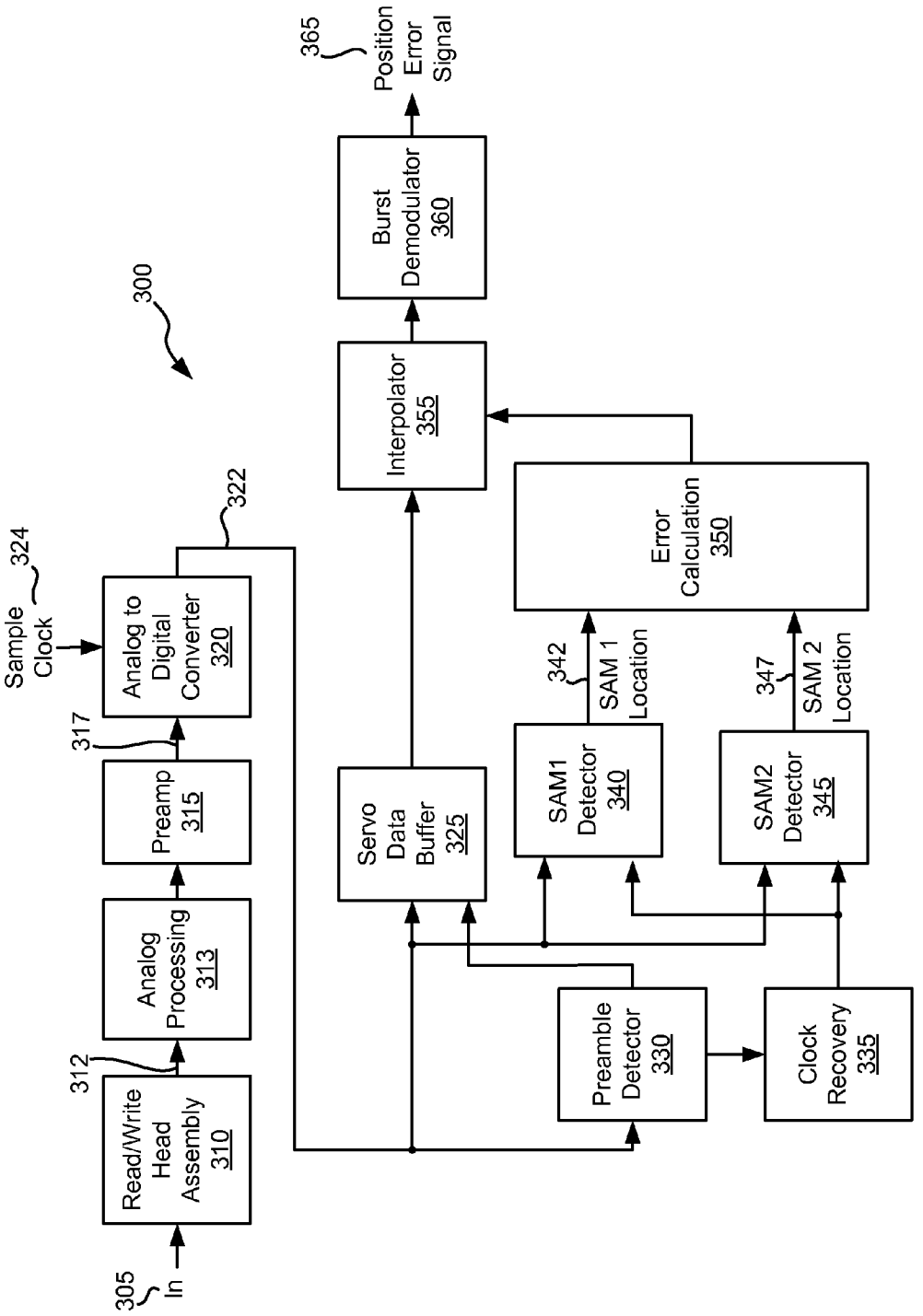

300
305
In
Read/Write Head Assembly 310
312
Analog Processing 313
Preamp 315
317
Analog to Digital Converter 320
322
Sample Clock
324
Servo Data Buffer 325
Interpolator 355
Burst Demodulator 360
365
Position Error Signal
Error Calculation 350
SAM1 Detector 340
342
SAM 1 Location
SAM2 Detector 345
347
SAM 2 Location
Preamble Detector 330
Clock Recovery 335

Fig. 3

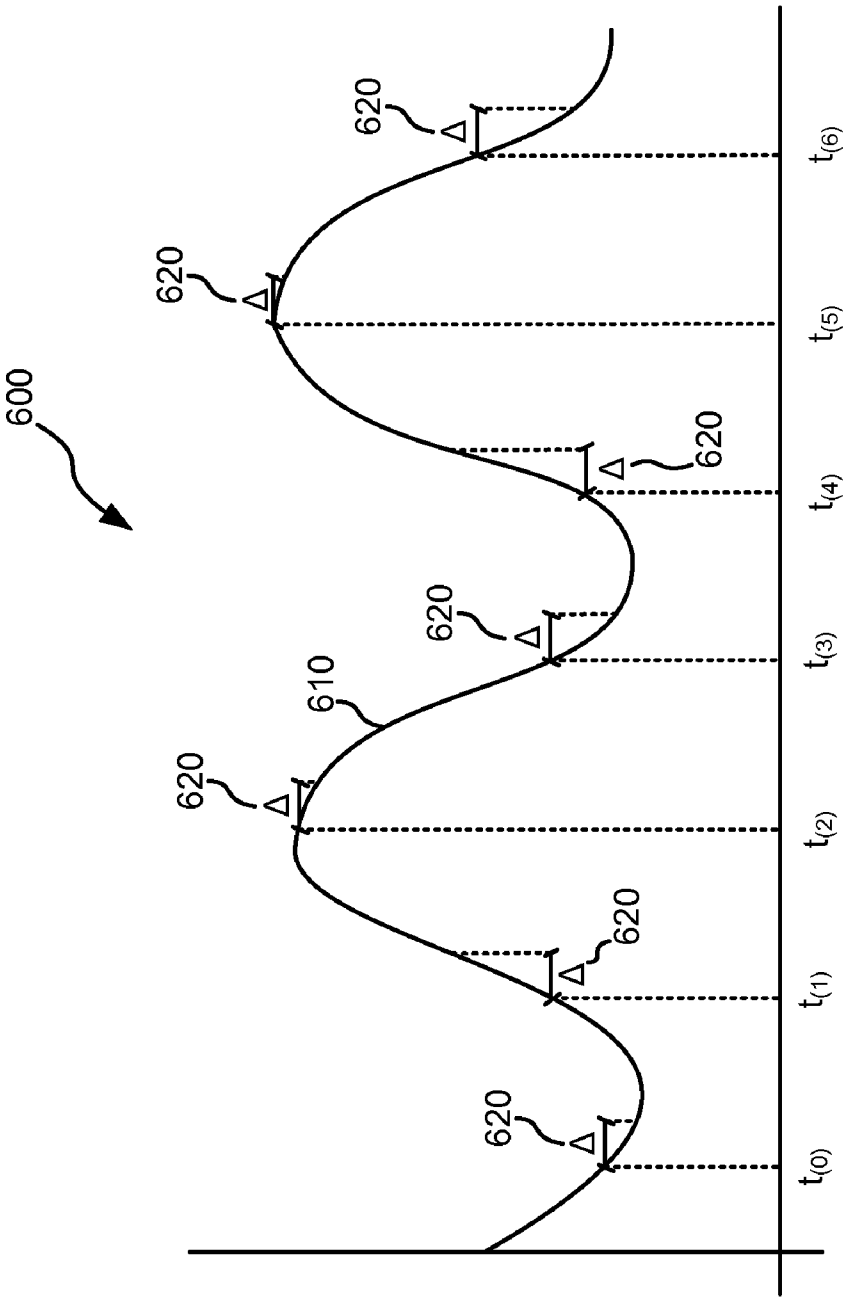


Fig. 5

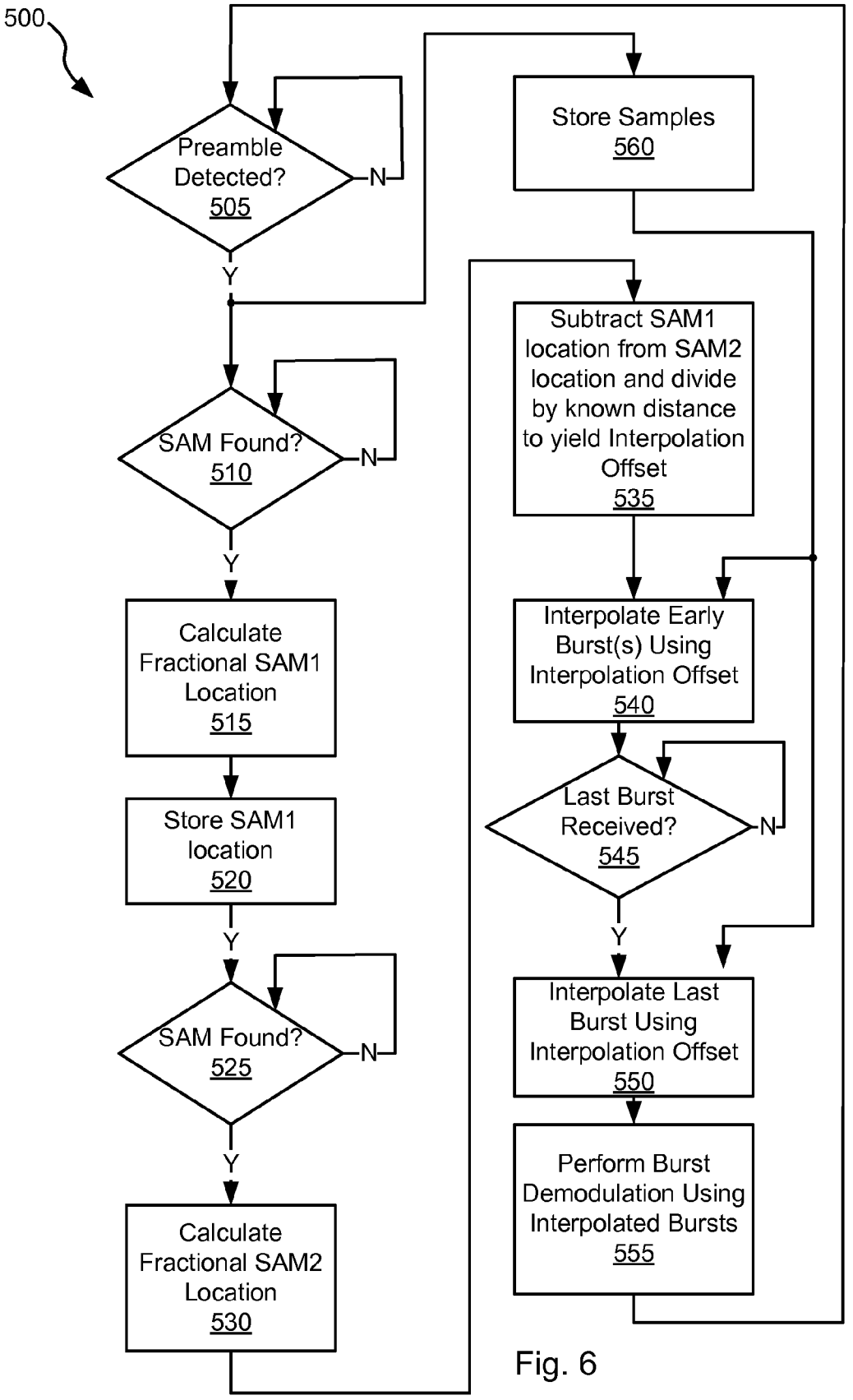

500
Preamble Detected? 505
N
Y
SAM Found? 510
N
Y
Calculate Fractional SAM1 Location 515
Store SAM1 location 520
Y
SAM Found? 525
N
Y
Calculate Fractional SAM2 Location 530
Store Samples 560
Subtract SAM1 location from SAM2 location and divide by known distance to yield Interpolation Offset 535
Interpolate Early Burst(s) Using Interpolation Offset 540
Last Burst Received? 545
N
Y
Interpolate Last Burst Using Interpolation Offset 550
Perform Burst Demodulation Using Interpolated Bursts 555

Fig. 6

SYSTEMS AND METHODS FOR IMPROVED SERVO DATA OPERATION

BACKGROUND OF THE INVENTION

[0001] The present invention is related to storage media, and more particularly to systems and methods for aligning a read/write head assembly in relation to a storage medium.

[0002] A typical storage medium includes a number of storage locations where data may be stored. Data is written to the medium within areas designated for user data by positioning a read/write head assembly over the storage medium at a selected location, and subsequently passing a modulated electric current through the head assembly such that a corresponding magnetic flux pattern is induced in the storage medium. To retrieve the stored data, the head assembly is positioned over a track containing the desired information and advanced until it is over the desired data. The previously stored magnetic flux pattern operates to induce a current in the head assembly, and the induced current may then be converted to an electrical signal representing the originally recorded data.

[0003] The storage locations on the storage medium are typically arranged as a serial pattern along concentric circles known as tracks. FIG. **1** shows a storage medium **100** with two exemplary tracks **150**, **155** indicated as dashed lines. The tracks are segregated by servo data written within wedges **160**, **165**. The servo data includes data and supporting bit patterns that are used for control and synchronization of the read/write head assembly over a desired storage location on storage medium **100**. In particular, the servo data traditionally includes a preamble pattern followed by a single sector address mark (SAM). The SAM is followed by a Gray code, and the Gray code is followed by burst information. It should be noted that while two tracks and two wedges are shown, hundreds of each would typically be included on a given storage medium. Further, it should be noted that a sector may have two or more burst fields depending upon the approach selected for determining position error.

[0004] Conventional servo data utilizes the preamble field to adjust timing and gain loops in an effort to synchronize sampling to data written to the storage medium. After the timing loops and gain loops are stable, the SAM, the Gray code and the burst information are processed to determine location on the storage medium and to generate a position error signal. Accurate determination of the timing and gain from the preamble is critical to proper processing of the servo data. For example, where the timing is not accurate, any position error signal will be correspondingly inaccurate. This inaccuracy can cause an increase in bit error rate due to improper positioning of the read/write head assembly in relation to the storage medium. To increase the accuracy of the timing and gain loops, longer preambles may be chosen. However, increasing the preamble length causes a corresponding reduction in storage density on the storage medium.

[0005] Hence, for at least the aforementioned reasons, there exists a need in the art for advanced systems and methods for increasing the accuracy of position error determination.

BRIEF SUMMARY OF THE INVENTION

[0006] The present invention is related to storage media, and more particularly to systems and methods for aligning a read/write head assembly in relation to a storage medium.

[0007] Various embodiments of the present invention provide systems for efficiently determining a position error of a head in relation to a storage medium. Such systems include a storage medium with a series of data. The series of data includes a first defined marker and a second defined marker located a distance from the first defined marker, and position location data. The systems further include a first detector circuit that is operable to detect the first defined marker and to establish a location of the first defined marker, and a second detector circuit that is operable to detect the second defined marker and to establish a location of the second defined marker. The systems further include an error calculation circuit and an interpolation circuit. The error calculation circuit is operable to calculate an interpolation offset based at least in part on the location of the first defined marker and the location of the second defined marker. The interpolation circuit is operable to interpolate the position location data and to provide an interpolated position location data. In some cases, the systems further include a burst demodulation circuit that generates a position error signal based at least in part on the interpolated position location data. In one or more instances of the aforementioned embodiments, the first detector circuit and the second detector circuit are identical. In other instances of the aforementioned embodiments, the first detector circuit and the second detector circuit have a substantial amount of common circuitry. For example, in one case, the location determination circuitry is common between the two detectors, but each detector has a different register holding a respective expected SAM pattern.

[0008] In some instances of the aforementioned embodiments, the series of data is sector data including a preamble pattern. The first defined marker is a first sector address mark and the second defined marker is a second sector address mark. In such instances, the systems further include a signal receiving circuit having an analog to digital converter that samples an analog input using a sampling clock operating at a frequency and a phase to create the series of samples, and a preamble detector and clock recovery circuit. The preamble detector and clock recovery circuit is operable to detect the preamble pattern within the sector data and to adjust at least one of the frequency and the phase based on the preamble pattern to create an adjusted sampling clock. The interpolation offset may be operable to at least in part compensate for a phase error in the adjusted sampling clock. In some cases, the location of the first defined marker includes a combination of fractional distance and an integer distance from a reference location.

[0009] In various instances of the aforementioned embodiment, the position location data includes at least a first burst pattern and a second burst pattern. In such cases, the first sector address mark is located after the preamble pattern and before the first burst pattern, and the second sector address mark is located after the first burst pattern and before the second burst pattern. In some cases, the sector data further includes a Gray code that is located after the first sector address mark and before the second sector address mark.

[0010] Other embodiments of the present invention provide methods for efficient determination of a position error. Such methods include providing a storage medium having a series of data. The series of data includes a first defined marker and a second defined marker located a distance from the first defined marker, and position location data. The series of data is received, and the first defined marker and second defined marker are detected. The location of both the first defined

marker and the second defined marker are identified, and an interpolation offset is calculated based at least in part on the first location and the second location. The position location data is interpolated using the interpolation offset to create interpolated position location data and a position error is determined using the interpolated position location data.

[0011] In some instances of the aforementioned embodiments, the series of data is sector data including a preamble pattern. The first defined marker is a first sector address mark and the second defined marker is a second sector address mark. In such instances, receiving the series of data includes receiving an analog input including the sector data, and sampling the analog input using a sampling clock operating at a frequency and a phase to generate at least a portion of the sector data. The preamble pattern is detected within the sector data. Based on the preamble pattern, one or both of the frequency and the phase are adjusted to yield an adjusted sampling clock. The analog input is then sampled using the adjusted sampling clock. In some cases, the interpolation offset is operable to at least in part compensate for a phase error in the adjusted sampling clock.

[0012] In some instances of the aforementioned embodiments, the first sector address mark is the same as the second sector address mark. In other instances, the first sector address mark is distinct from the second sector address mark. In various instances of the aforementioned embodiments, the position location data includes at least a first burst pattern and a second burst pattern. In such instances, the first sector address mark is located after the preamble pattern and before the first burst pattern, and the second sector address mark is located after the first burst pattern and before the second burst pattern. In some cases, the sector data includes a Gray code that is located after the first sector address mark and before the second sector address mark. In various instances of the aforementioned embodiments, the position location data includes at least a first burst pattern, a second burst pattern and a third burst pattern. In such instances, the first sector address mark is located after the preamble pattern and before the first burst pattern, and the second sector address mark is located after the second burst pattern and before the third burst pattern.

[0013] In some cases, the storage medium further includes another sector data that has the same preamble pattern, first sector address mark and second sector address mark. In one or more instances of the aforementioned embodiments, identifying the first location of the first sector address mark includes performing a first fractional location calculation, and identifying the second location of the second sector address mark includes performing a second fractional location calculation. In some instances of the aforementioned embodiments, calculating the interpolation offset includes subtracting the first location from the second location and dividing the result by the distance.

[0014] Yet other embodiments of the present invention provide storage media that include a first sector data set having a preamble pattern, a first sector address mark, a second sector address mark, a first burst pattern, and a second burst pattern; and a second sector data set having the preamble pattern, the first sector address mark, the second sector address mark, the first burst pattern, and the second burst pattern. The first burst pattern is located before the second burst pattern, the first sector address mark is located after the preamble pattern, and the second sector address mark is located after the first burst pattern.

[0015] This summary provides only a general outline of some embodiments of the invention. Many other objects, features, advantages and other embodiments of the invention will become more fully apparent from the following detailed description, the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] A further understanding of the various embodiments of the present invention may be realized by reference to the figures which are described in remaining portions of the specification. In the figures, like reference numerals are used throughout several drawings to refer to similar components. In some instances, a sub-label consisting of a lower case letter is associated with a reference numeral to denote one of multiple similar components. When reference is made to a reference numeral without specification to an existing sub-label, it is intended to refer to all such multiple similar components.

[0017] FIG. **1** depicts an exemplary, existing storage medium including user data areas and intervening servo data wedges;

[0018] FIG. **2** depicts an enhanced servo data pattern in accordance with various embodiments of the present invention;

[0019] FIG. **3** is a block diagram of a system for processing enhanced servo data patterns in accordance with some embodiments of the present invention;

[0020] FIG. **4** is a timing diagram illustrating the process for determining SAM location that may be used in accordance with different embodiments of the present invention;

[0021] FIG. **5** is a timing diagram illustrating the process of interpolating burst information that may be used in accordance with some embodiments of the present invention; and

[0022] FIG. **6** is a flow diagram of a method in accordance with one or more embodiments of the present invention for processing an enhanced servo data pattern.

DETAILED DESCRIPTION OF THE INVENTION

[0023] The present invention is related to storage media, and more particularly to systems and methods for aligning a read/write head assembly in relation to a storage medium.

[0024] Turning to FIG. **2** an enhanced servo data pattern **200** is shown in accordance with various embodiments of the present invention. Enhanced servo data pattern **200** includes a preamble **204**, a first servo address mark (SAM**1**) **206**, a Gray code **208**, a first burst information (Burst**1**) **210**, a second servo address mark (SAM**2**) **212**, and a second burst information (Burst**2**) **214**. Enhanced servo data pattern **200** is sandwiched between two user data areas **202**, **216**. Gray code **208** is encoded information about track location and may be any Gray code known in the art, and Burst**1** **210** and Burst**2** **214** may be any burst information known in the art. It should be noted that more than two fields of burst information may be used depending upon the particular burst demodulation scheme implemented. For example, in some embodiments of the present invention four fields of burst information may be used. SAM**1** **206** is used to distinguish servo sectors from user data regions of the storage medium. SAM**2** **212** is used in conjunction with SAM**1** **206** to provide a correction to any phase error remaining after the processing of preamble **204**. SAM**1** **206** and SAM**2** **212** may each include any SAM pattern known in the art. In some cases, SAM**2** **212** has the same

pattern as SAM1 **206**, while in other cases, the pattern of SAM2 **212** is distinct from pattern of SAM1 **206**.

[0025] SAM1 **206** and SAM2 **212** are dispersed across enhanced servo data pattern **200** and are used to provide an input for interpolating Burst1 **210** and Burst2 **214**. In some cases, SAM1 **206** and SAM2 **212** are placed as far apart as possible without incurring any additional latency on a position error signal derived from processing Burst1 **210** and Burst2 **214**. Thus, for example where enhanced servo data pattern **200** is extended to include four burst fields, SAM1 **206** may be placed somewhere in the pattern before the first burst field and SAM2 may be placed in the pattern before the last burst field. Similar to existing preamble patterns, preamble **204** is a periodic pattern that is used by a data processing system to adjust timing and gain loops. However, due to the phase error correction ability created by including SAM1 **206** and SAM2 **212** in enhanced servo data pattern **200**, preamble **204** can be shorter than a corresponding preamble in a traditional servo data pattern. It should be noted that in some cases spacers of defined bit periods are placed between one or more of Gray code **208** and Burst1 **210**, Burst1 **210** and SAM2 **212**, SAM2 **212** and Burst2 **214**, and Burst2 **214** and user data **216**.

[0026] In some cases, the reduction in the length of preamble **204** compared with a traditional preamble is greater than the number of bit periods required by SAM2 **212**. In such cases, enhanced servo data pattern **200** offers either an increase in the accuracy of the position error generated by processing of burst information without increasing the number of bit periods associated with the servo data sector, or providing the same level of accuracy of the position error generated by processing the burst information while decreasing the number of bit periods associated with the servo data sector. Based upon the disclosure provided herein, one of ordinary skill in the art will recognize a variety of other advantages that may be achieved through implementations of one or more embodiments of the present invention.

[0027] In use, a data processing system receives a series of samples corresponding to preamble **204**. The samples are used to extract timing information and gain information that are used to adjust the phase and/or frequency of the sampling interval used to process later portions of enhanced servo data pattern **200**. As mentioned above, preamble **204** may be relatively short resulting in some error in the sampling interval. A subsequent series of samples includes SAM1 **206** which is processed and a location of the SAM1 **206** is stored. Gray code **208** is then processed using conventional means to obtain track information. This is followed by reception and buffering of samples associated with Burst1 **210**. A subsequent series of samples includes SAM2 **214** which is processed and a location of the SAM2 **214** is stored. The location of SAM1 **206** and SAM2 **214** are mathematically combined and a resulting interpolation offset is used to interpolate samples corresponding to Burst1 **210** that have been stored to a buffer and to process samples corresponding to Burst2 **214**. The interpolated burst samples may then be used in a conventional burst demodulation scheme to generate a position error signal. This position error signal may be used to adjust the location of a read/write head assembly in relation to a storage medium. The interpolation process yields a more accurate representation of Burst1 **210** and Burst2 **214** which in turn results in a position error signal exhibiting a higher degree of accuracy. This accuracy allows for better positioning of the read/write head assembly and a corresponding increase in signal to noise ratio and decrease in bit error rate.

[0028] Turning to FIG. **3**, a block diagram of a data processing system **300** tailored for processing enhanced servo data patterns is shown in accordance with some embodiments of the present invention. Data processing system **300** includes a read/write head assembly **310** that senses a magnetic field **305** stored on a storage medium (not shown) and converts the sensed information to an electrical signal **312**. Electrical signal **312** is provided to an analog processing block **313** as is known in the art, and the output of analog processing block **313** is provided to a preamplifier **315** that amplifies the signal and provides a corresponding amplified signal **317**. An analog to digital converter **320** receives amplified signal **317** and converts it to a series of digital samples **322** each corresponding to a time instant governed by a sample clock **324**. Digital samples **322** are provided to a preamble detector **330** that operates to detect a pre-defined periodic preamble pattern (e.g., preamble **204**). Once detected, the defined periodic preamble pattern is used by a clock recovery circuit **335** to adjust the phase/frequency of sample clock **324** using recovery processes that are known in the art.

[0029] Once the preamble is found, a servo data buffer **325** begins storing the series of digital samples **322** received from analog to digital converter **320**. Further, digital samples **322** are provided to a SAM detection circuit **340** designed to detect a first SAM pattern (e.g., SAM1 **206**), and to a SAM detection circuit **345** designed to detect a second SAM pattern (e.g., SAM2 **212**). In some cases, SAM2 **212** has the same pattern as SAM1 **206**. In such cases, SAM detection circuit **340** may be identical to SAM detection circuit **345**. In other cases, the pattern of SAM2 **212** is distinct from pattern of SAM1 **206**. In such cases, SAM detection circuit **340** may be similar to SAM detection circuit **345**, but the two circuits are sufficiently different to allow for detection of the distinct patterns corresponding to SAM1 **206** and SAM2 **212**. In particular embodiments of the present invention, SAM detection circuit **340** and SAM detection circuit **345** are implemented as a single circuit capable of indicating identifying both SAM1 **206** and SAM2 **212**. In such cases where SAM1 is different from SAM2, a selectable comparison register may be included in the common SAM detection circuit to allow for detection of SAM1 **206** during one interval and for detection of SAM2 **212** during a subsequent interval.

[0030] Once the first SAM pattern is detected (e.g., SAM1 **206**), a SAM1 location signal **342** is provided to an error calculation circuit **350** that indicates a time corresponding to the detection of the first SAM pattern. Subsequently, a second SAM pattern is detected (e.g., SAM2 **212**), and a SAM2 location signal **347** is provided to error calculation circuit **350**. Similarly, SAM **2** location signal **347** indicates a time corresponding to the detection of the second SAM pattern. In some cases, SAM detection circuit **340** and SAM detection circuit **345** each provide a respective SAM location signal that is an integer number of time periods from a reference point. In other cases, accuracy is increased where SAM detection circuit **340** and SAM detection circuit **345** each provide the aforementioned integer number of time periods from the reference point augmented by a fractional offset. The operation of one exemplary circuit for determining integer SAM locations and fractional SAM locations is discussed in relation to FIG. **4** below. Based upon the disclosure provided herein, one of ordinary skill in the art will recognize a variety of other approaches that may be used to determine SAM1 location **342** and SAM2 location **347** in accordance with different embodiments of the present invention.

[0031] FIG. **4** is a timing diagram **400** that illustrates the process for determining SAM location that may be used in relation to different embodiments of the present invention. In particular, in a period **410** before the pattern corresponding to a SAM is received, the signal level provided by a SAM detector included in SAM detection circuit **345** is relatively low. Once the SAM is detected during a SAM pattern period **420** the signal level provided by the SAM detector increases. During SAM pattern period **420**, the signal from the SAM detector is sampled one or more times (e.g., at times t(x−1), t(x) and t(x+1)). The integer location of the SAM is defined to be the location (i.e., time periods from a reference point) where the signal from the SAM detector exhibits its highest value. Where only a less accurate integer value is used, the SAM location is simply the time of corresponding to the highest sample value of the signal from the SAM detector (e.g., t(x)).

[0032] In some cases, a more refined fractional SAM location value may be determined. Such an approach may involve calculating the location of the maximum value of the signal from the SAM detector based on the highest sample value and the two sample values on either side of the highest sample value (e.g., sample(x) corresponding to t(x), sample(x−1) corresponding to t(x−1), and sample(x+1) corresponding to t(x+1)) in accordance with the following equation:

$$\phi = \frac{\text{sample}(x-1) + \text{sample}(x+1)}{2 * \text{sample}(x)}.$$

The SAM location is then calculated by adding the fractional SAM location value to the location corresponding to the highest sample value (e.g., t(x)) to yield the actual SAM location according to the following equation:

$$\text{SAM location} = t(x) + \phi.$$

[0033] SAM**1** location **342** and SAM**2** location **347** are combined by an error calculation circuit **350** to generate an interpolation offset **352**. In particular, the difference between SAM**1** location **347** and SAM**2** location **342** is calculated and divided by a known distance between SAM**1** location **342** and SAM**2** location **347** (i.e., the known distance between SAM**1** **206** and SAM **2** **212**) as set forth in the following equation:

$$\text{Interpolation Offset} = \frac{SAM2 \text{ Location } 347 - SAM1 \text{ Location } 342}{\text{Known Distance}}.$$

The known distance is defined at the time servo data is written to the storage medium, and is the expected number of bit periods between SAM**1** **206** and SAM**2** **212**. In some cases, the known distance is increased as much as possible (resulting in a corresponding increase in the difference between SAM**2** location **347** and SAM**1** location **342**) to increase the accuracy of the above mentioned equation. Increasing the known distance is done by moving SAM**2** **212** farther upstream from SAM**1** **206**. In some cases, SAM**2** is placed just before the final burst field (e.g., Burst**2** **214**) in the servo data. Thus, for example, where two burst fields are employed, SAM**2** **212** is moved to a position in the servo data pattern preceding the second burst field. As another example, where four burst fields are employed, SAM **2** **212** is moved to a position in the servo data pattern preceding the fourth burst field. This placement allows for maximizing the distance between SAM**1** and SAM**2** without further delaying processing of the final burst field (e.g., Burst**2** **214**) prior to the start of user data **216**. Based on the disclosure provided herein, one of ordinary skill in the art will appreciate other placements of SAM**1** **206** and SAM**2** **212** that may be used to maximize processing performance. For example, in some cases, SAM**2** **212** is moved after the last burst field (e.g., Burst **2** **214**) with an appropriate spacer after SAM**2** **212** to allow sufficient time for interpolation and processing of burst information from the final burst field before the start of user data **216**.

[0034] The data corresponding to two or more burst fields included in the servo data pattern (e.g., Burst**1** **210** and Burst**2** **214**) is then interpolated using an interpolator circuit **355**. In particular, the burst information exists a known number of bit periods from SAM**1** location **342**. This distance offset from SAM**1** location **342** is incremented by the calculated interpolation offset to yield error corrected samples corresponding to Burst**1** **210** and Burst**2** **214**. FIG. **5** is a timing diagram **600** illustrating a process for interpolating burst information that may be used in accordance with some embodiments of the present invention. In timing diagram **600**, a series of samples corresponding to time increments $t_{(0)}$, $t_{(1)}$, $t_{(2)}$, $t_{(3)}$, $t_{(0)}$, $t_{(5)}$, and $t_{(6)}$ are shown along an exemplary continuous output **610**. The time increments are a defined distance from SAM**1** location **342** that correspond to burst information. The interpolation process includes adjusting each of the samples forward by an interpolation offset **620** identified by the symbol A. Such a process results in a correction for any phase error remaining after the processing of the earlier processed preamble (e.g., preamble **204**). It should be noted that the depicted interpolation process is exemplary and that other interpolation approaches may be used in accordance with different embodiments of the present invention.

[0035] Next, returning to FIG. **3**, the corrected burst information is provided to a burst demodulator circuit **360** that performs burst demodulation. Such burst demodulation may be any burst demodulation known in the art. For example, where two burst fields are used in the servo data, a two burst demodulation process may be used. As another example, where four burst fields are used in the servo data, a four burst demodulation process may be used. Burst demodulator circuit **360** provides a position error signal **365** that may be used to properly place read/write head assembly **310** in relation to a storage medium (not shown) from which magnetic field **305** is derived.

[0036] Turning to FIG. **6**, a flow diagram **500** depicts a method in accordance with one or more embodiments of the present invention for processing an enhanced servo data pattern. Following flow diagram **500**, a series of digital samples is received and continuously queried to determine if a predefined periodic preamble pattern is incorporated in the series of samples (block **505**). Where a periodic preamble pattern is not detected (block **505**), the process of comparing to detect the preamble pattern is continued. Otherwise, where a predefined periodic preamble is detected (block **505**) a process of querying to determine if a SAM pattern is found (block **510**). Preamble detection may be performed using any preamble detection process known in the art. Further, it should be noted that while the preamble pattern is being processed, timing and gain feedback is generated that is used to govern the sampling of the received information from which the series of samples is derived. Once a SAM is found (block **510**), a fractional

SAM1 location is calculated (block **515**). Fractional SAM1 location may be calculated in accordance with the following equation:

$$SAM\ \text{Location} = t(x) + \frac{\text{sample}(x-1) + \text{sample}(x+1)}{2 * \text{sample}(x)},$$

Where sample(x) corresponds to the sample most likely corresponding to the actual location of the detected SAM, sample(x−1) and sample(x+1) correspond to the samples on either side of sample(x), and t(x) corresponds to the sample time of sample(x). The calculated fractional SAM1 location is then stored (block **520**).

[0037] Once the first SAM is processed (blocks **510-520**), the received series of samples is queried for a subsequent SAM (block **525**). In some cases, the subsequent SAM has the same pattern as the first SAM. In other cases, the subsequent SAM has a pattern that is distinct from the first SAM. Where the subsequent SAM is found (block **525**), a fractional SAM2 location is calculated (block **530**). Fractional SAM2 location may be calculated using the same approach described above in relation to block **515**. The fractional SAM1 location is then subtracted from the fractional SAM2 location, and the difference is divided by an expected or known distance between SAM1 and SAM2 (block **535**) to yield an interpolation offset in accordance with the following equation:

$$\text{Interpolation Offset} = \frac{SAM2\ \text{Location} - SAM1\ \text{Location}}{\text{Known Distance}}.$$

The known distance is defined at the time servo data is written to the storage medium, and is the expected number of bit periods between SAM1 **206** and SAM2 **212** in the servo data pattern. As mentioned above, in some cases the known distance is increased as much as possible to increase the accuracy of the above mentioned equation. Increasing the known distance is done by moving SAM2 **212** farther upstream from SAM1 **206**. In some cases, SAM2 is placed just before the final burst field (e.g., Burst2 **214**) in the servo data. Thus, for example, where two burst fields are employed, SAM2 **212** is moved to a position in the servo data pattern preceding the second burst field. As another example, where four burst fields are employed, SAM **2 212** is moved to a position in the servo data pattern preceding the fourth burst field. This placement allows for maximizing the distance between SAM1 and SAM2 without further delaying processing of the final burst field (e.g., Burst2 **214**) prior to the start of user data **216**. Based on the disclosure provided herein, one of ordinary skill in the art will appreciate other placements of SAM1 **206** and SAM2 **212** that may be used to maximize processing performance. For example, in some cases, SAM2 **212** is moved after the last burst field (e.g., Burst **2 214**) with an appropriate spacer after SAM2 **212** to allow sufficient time for interpolation and processing of burst information from the final burst field before the start of user data **216**.

[0038] Beginning sometime before the expected receipt of burst information, the received series of samples are stored (block **560**). The stored samples are received from an analog to digital converter that is sampling an analog input signal using a sampling clock with a phase and frequency adjusted based on the earlier received preamble. A portion of the stored samples corresponding to one or more burst fields received prior to the second SAM are retrieved and interpolated using the previously calculated interpolation offset (block **540**). This process results in burst information that is corrected for any phase offset remaining after synchronization using the preamble.

[0039] The received samples are further processed where it is determined if the last expected burst is received (block **545**). Where the last expected burst is received (block **545**), the series of samples corresponding to the last burst are interpolated as received using the same interpolation offset used to interpolate the earlier buffered burst information. This interpolation process results in a complete set of burst information that has been corrected to account for any phase offset remaining after synchronization using the preamble. At this point, the corrected burst information is provided to a burst demodulator circuit that performs burst demodulation using any demodulation approach known in the art.

[0040] In conclusion, the invention provides novel systems, devices, methods and arrangements for accessing a storage medium. While detailed descriptions of one or more embodiments of the invention have been given above, various alternatives, modifications, and equivalents will be apparent to those skilled in the art without varying from the spirit of the invention. For example, one or more embodiments of the present invention may be applied to various data storage systems and digital communication systems, such as, for example, tape recording systems, optical disk drives, wireless systems, and digital subscribe line systems. Therefore, the above description should not be taken as limiting the scope of the invention, which is defined by the appended claims.

What is claimed is:

1. A system for efficiently determining a position error of a head in relation to a storage medium, the system comprising:

a storage medium including a series of data; wherein the series of data includes a first defined marker and a second defined marker located a distance from the first defined marker, and wherein the series of data further includes position location data;

a first detector circuit operable to detect the first defined marker and to establish a location of the first defined marker;

a second detector circuit operable to detect the second defined marker and to establish a location of the second defined marker;

an error calculation circuit, wherein the error calculation circuit is operable to calculate an interpolation offset based at least in part on the location of the first defined marker and the location of the second defined marker; and

an interpolation circuit, wherein the interpolation circuit is operable to interpolate the position location data and to provide an interpolated position location data.

2. The system of claim **1**, wherein the system further comprises:

a burst demodulation circuit, wherein the burst demodulation circuit generates a position error signal based at least in part on the interpolated position location data.

3. The system of claim **1**, wherein the series of data is sector data including a preamble pattern, wherein the first defined marker is a first sector address mark, wherein the second defined marker is a second sector address mark, and wherein

the system further includes a signal receiving circuit including:

an analog to digital converter that samples an analog input using a sampling clock operating at a frequency and a phase to create the series of samples; and

a preamble detector and clock recovery circuit operable to detect the preamble pattern within the sector data and to adjust at least one of the frequency and the phase based on the preamble pattern to create an adjusted sampling clock.

4. The system of claim **3**, wherein the interpolation offset is operable to at least in part compensate for a phase error in the adjusted sampling clock.

5. The system of claim **3**, wherein the position location data includes at least a first burst pattern and a second burst pattern, wherein the first sector address mark is located after the preamble pattern and before the first burst pattern, and wherein the second sector address mark is located after the first burst pattern and before the second burst pattern.

6. The system of claim **5**, wherein the sector data includes a Gray code, and wherein the Gray code is located after the first sector address mark and before the second sector address mark.

7. The system of claim **1**, wherein the first detector circuit and the second detector circuit are identical.

8. The system of claim **1**, wherein the first detector circuit and the second detector circuit share the same circuitry.

9. The system of claim **3**, wherein the location of the first defined marker includes a combination of fractional distance and an integer distance from a reference location.

10. A method for efficient determination of a position error, the method comprising:

providing a storage medium including a series of data; wherein the series of data includes a first defined marker and a second defined marker located a distance from the first defined marker, and wherein the series of data further includes position location data;

receiving the series of data;

detecting the first defined marker;

identifying a first location of the first defined marker;

detecting the second defined marker;

identifying a second location of the second defined marker;

calculating an interpolation offset based at least in part on the first location and the second location;

interpolating the position location data based on the interpolation offset to create interpolated position location data; and

determining a position error using the interpolated position location data.

11. The method of claim **10**, wherein the series of data is sector data including a preamble pattern, wherein the first defined marker is a first sector address mark, wherein the second defined marker is a second sector address mark, and wherein receiving the series of data includes:

receiving an analog input including the sector data;

sampling the analog input using a sampling clock operating at a frequency and a phase to generate at least a first portion of the sector data;

detecting the preamble pattern within the sector data;

adjusting at least one of the frequency and the phase based on the preamble pattern to create an adjusted sampling clock; and

sampling the analog input using the adjusted sampling clock to generate at least a second portion of the sector data.

12. The method of claim **11**, wherein the interpolation offset is operable to at least in part compensate for a phase error in the adjusted sampling clock.

13. The method of claim **11**, wherein the first sector address mark is the same as the second sector address mark.

14. The method of claim **11**, wherein the position location data includes at least a first burst pattern and a second burst pattern, wherein the first sector address mark is located after the preamble pattern and before the first burst pattern, and wherein the second sector address mark is located after the first burst pattern and before the second burst pattern.

15. The method of claim **14**, wherein the sector data further includes a Gray code, and wherein the Gray code is located after the first sector address mark and before the second sector address mark.

16. The method of claim **11**, wherein the position location data includes at least a first burst pattern, a second burst pattern and a third burst pattern, wherein the first sector address mark is located after the preamble pattern and before the first burst pattern, and wherein the second sector address mark is located after the second burst pattern and before the third burst pattern.

17. The method of claim **11**, wherein the sector data is a first sector data, wherein the storage medium further includes a second sector data including the same preamble pattern, first sector address mark and second sector address mark.

18. The method of claim **11**, wherein identifying the first location of the first sector address mark includes performing a first fractional location calculation, and wherein identifying the second location of the second sector address mark includes performing a second fractional location calculation.

19. The method of claim **11**, wherein calculating the interpolation offset includes subtracting the first location from the second location and dividing the result by the distance.

20. A storage medium, wherein the storage medium comprises:

a first sector data set, wherein the first sector data set includes a preamble pattern,

a first sector address mark, a second sector address mark, a first burst pattern, and a second burst pattern;

a second sector data set, wherein the second sector data set includes the preamble pattern, the first sector address mark, the second sector address mark, the first burst pattern, and the second burst pattern;

wherein the first burst pattern is located before the second burst pattern, wherein the first sector address mark is located after the preamble pattern, and wherein the second sector address mark is located after the first burst pattern.

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